HANDOUT 4-1

Case Study Number 4-1 Solution

Estimating PM_{10} and $PM_{2.5}$ Emissions from Locomotives

Question 1: Are the emission estimation methodologies the same for long haul and switchyard locomotives?
Answer: The activity data for both line-haul and switchyard locomotives are based on estimates of the gallons of distillate fuel oil consumed. However, the data provided for each requires that a different approach be used to estimate fuel consumption.

Question 2: What PM emission factors are applicable to locomotives?
Answer: The PM emissions factors that should be applied to the activity data are the same factors that were used in the NEI (listed in Table 4-9 of the Student Manual). In addition, it is assumed that 92% of PM_{10} is $PM_{2.5}$.

Question 3: What is the basis of the activity data for locomotives?
Answer: The activity data are based on an estimate of the gallons of distillate fuel oil consumed.

Question 4: What is the methodology for estimating PM_{10} and $PM_{2.5}$ emissions for line haul locomotives? For switchyard locomotives?
Answer: Since the activity data is based on gallons of fuel consumed and the emission factor is in terms of grams per gallon of fuel consumed, estimating emissions is based on using the available data to calculate fuel consumption.

In the case of line haul locomotives, traffic density can be estimated for each line segment by multiplying gross tonnage by the total miles of track. The next step in the emissions calculation process is to estimate the fuel consumption by multiplying the estimated traffic density by the fuel consumption index. The third step is to multiply the fuel consumption (gallons per year) by the PM_{10} emission factor (grams per gallon) to obtain a PM_{10} emission estimate. The fourth step is to apply a conversion factor to convert grams to tons of emissions. The final step is to calculate the $PM_{2.5}$ emission by applying the particle size multiplier of 0.92 to the PM_{10} emission estimate. These steps are done for each of the three line segments; however, the third line segment has zero gross tons operating on that segment, so that segment has zero emissions.

In the case of switchyard locomotives, the first step is to multiply the number of switch yard locomotives that was provided by the railroad company by EPA's default value for fuel consumed for both switchyard locomotives to obtain a fuel consumption estimate. The next step is to multiply the fuel consumption (gallons per year) by the PM_{10} emission factor (grams per gallon). The third step is to apply a conversion factor to convert grams to tons of emissions. The final step is to calculate the $PM_{2.5}$ emission by applying the particle size multiplier of 0.92 to the PM_{10} emission estimate.

Question 5: What is your estimate of the PM_{10} and $PM_{2.5}$ emissions from long-haul locomotives?
Answer: Line haul locomotive emissions are estimated for line segment 1 as follows:

Step 1: Calculate traffic density
15 million GT x 17 miles = 255 million gross ton miles

Step 2: Estimate fuel consumption
255 million gross ton miles x 0.00139 gal./gross ton-mile = 354,450 gallons/year

Step 3: Estimate emissions
354,450 gallons/year x 6.7 grams/gallon = 2,374,815 grams/year

Step 4: Convert units to tons
2,374,815 grams/yr ÷ 453.6 grams/pound = 5,235.5 pounds/year
5,235.5 pounds/year ÷ 2,000 pounds/ton = 2.62 tons of PM_{10}/year.

Step 5: Calculate $PM_{2.5}$ emissions
2.62 tons of PM_{10}/year x 0.92 = 2.4 tons of $PM_{2.5}$/year

These steps are done for each of the three line segments; however, the third line segment has zero gross tons operating on that segment, so that segment has zero emissions.

The following table presents the collected data and the data that was calculated for each of the line segments and the sum of total emissions for the entire inventory area.

Summary of Line Haul Emission Calculations

Line Segment	Gross Tonnage Million GT	Distance in Miles	Density Million GTM	Fuel Use in Gallons	PM_{10} Emissions, TPY
1	15.0	17.0	255.0	354,450	2.62
2	8.0	15.0	120.0	166,800	1.23
3	0.0	10.5	0.0	0	0
Total	23	42.5	375	521,250	3.86

Question 6: What is your estimate of the PM_{10} and $PM_{2.5}$ emissions from switchyard locomotives?
Answer: Switchyard locomotive emissions are estimated as follows:

Step 1: Estimate fuel consumption
82,500 gal. fuel consumed/switchyard locomotive x 1.8 = 148,500 gallons/year

Step 2: Estimate emissions
148,500 gallons/year x 9.2 grams/gallon = 1,366,200 grams PM_{10}/year

Step 3: Convert units to tons

1,366,200 grams/yr ÷ 453.6 grams/pound = 3,011.9 pounds/year

3,011.9 pounds/year ÷ 2,000 pounds/ton = 1.51 tons of PM_{10}/year.

Step 4: Calculate $PM_{2.5}$ emissions

1.51 tons of PM_{10}/year x 0.92 = 1.39 tons of $PM_{2.5}$/year

The following table presents the collected data and the data that was calculated for each switchyard and the sum of total emissions for the entire inventory area.

Summary of Switchyard Emission Calculations

Switch Yard	EPA Estimated Yearly Fuel Consumption	Number of Switchyard Locomotives	Fuel Use in Gallons	PM_{10} Emissions, TPY
1	82,500	1.3	107,250	1.09
2	82,500	0.5	41,250	0.42
Total		1.8	148,500	1.51

Question 7: Why does the railroad data on switchyards show fractions of switchyard locomotives in use in each switchyard?
Answer: This particular railroad operates two switchyards and provided an estimate of how often throughout the year each yard was operating. Because EPA assumes that each locomotive in a switchyard operates 24 hours a day, 365 days a year, locomotives operating less than this are considered fractions of a locomotive. This explains why the data shows fractions of switchyard locomotives in use in each switchyard.

Question 8: Do emissions for each line segment and switchyard need to be calculated individually?
Answer: As shown in this case study, for both line haul and switchyard locomotives, emissions can be estimated individually for each line segment or switchyard and then added together to obtain a total for the inventory area OR total fuel consumption can be estimated for all line haul locomotives and switchyards in the study area. In the latter case, the emission factor is applied to the total fuel consumption to estimate total emissions for the inventory area. In the case study the approach of estimating emissions individually was used for estimating emissions from line haul locomotives. The approach of estimating fuel consumption for all locomotives before applying the emission factor was used for switchyard locomotives.

Question 9: How can PM_{10} and $PM_{2.5}$ emissions be estimated for locomotives of the smaller company that was not able to provide gross tonnage data?
Answer: Another smaller railroad company was operating in the inventory area. However, this railroad company did not have records on the gross tonnage to allow the

traffic density to be estimated. In this case, the fuel consumption for that railroad could be estimated by multiplying the railroad's total fuel consumption by the percent of the railroad's track mileage in the inventory area. This estimated fuel consumption could then be multiplied by the emission factor and the particle size multiplier to obtain emissions estimates for PM_{10} and $PM_{2.5}$.

For example, assuming the railroad consumes 25,000 gallons of fuel per year and 90 percent of the railroad's track lies within the inventory area, the inventory area fuel consumption is: 25,000 gal x 90 percent = 22,500 gal. PM_{10} emissions are then calculated by applying the emission factor to the estimated fuel consumption as follows: 22,500 gal/year x 0.0148 lbs/gal = 333 lbs/year = 0.17 tons/year. This can be added to the emission estimate for the larger railroad company to estimate total PM_{10} emissions for the entire inventory area.